STUDIES ON THE BREEDING HABITS AND YOUNG OF THE COPPERHEAD, *AGKISTRODON MOKASEN* BEAUVOIS, WITH SOME OBSERVATIONS ON OVOVIVIPARITY

by

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INTRODUCTION

The scarcity of accurate information on the breeding habits and life histories of the nearctic pit vipers of America has been made quite obvious by the recent development of interest in the biology of poisonous snakes. In an effort to fill some of the gaps in our knowledge of these interesting animals, some studies on the local crotalid snakes of Eastern Kansas were undertaken in the fall of 1925. As the Copperhead, Agkistrodon mokasen Beauvois, (Plate I) proved to be the most easily obtainable pit viper of this region, it was selected for a more intensive study.

During the years 1925 to 1927 this work was carried on in the Museum of Ottawa University, Ottawa, Kansas, and since the fall of 1927 in the Zoological Laboratory of the Kansas State Agricultural College, Manhattan, Kansas. The writer is grateful to President F. Erdmann Smith and Dr. W. B. Wilson of Ottawa University, and to Dr. R. K. Nabours of the Department of Zoology, Kansas State Agricultural College for many kindnesses in providing facilities for carrying on this work; to Dr. G. E. Johnson, Department of Zoology, Kansas State Agricultural College, and Dr. Frank N. Blanchard, Department of Zoology, University of Michigan, for advice and criticisms during the progress of these

studies; and to Leonora K. Gloyd for assistance with the microtechnique.

MATERIALS

The snakes used were collected in the following localities in Eastern Kansas: "Gould's Ford" near Ottawa (Franklin County), Fontana (Miami County), La Cygne (Linn County), Manhattan (Riley County), Irving (Marshall County), and Xenia (Bourbon County). Larger numbers were taken in the spring and fall but a few were secured during each of the summer months.

Those kept for observation alive were provided with roomy cages, were supplied with water at all times and food at frequent intervals. White rats or mice were bred in the laboratory to insure a dependable source of snake food and English sparrows were sometimes available. The laboratory cages were for the most part unexposed to sunlight. In the spring of 1929, however, a series of cages was placed out of doors where some sunshine and shade were to be had almost the entire day and, as shown by their increased readiness to take food and the regularity and facility with which they shed their skins, the snakes kept outside appeared to have much better general health than those indoors. Gravid females were separated in glass-topped boxes 4 x 8 x 10

inches in size until after the birth of their young.

The Gould's Ford region, in which most of the field observations were made, is on Middle Creek in Franklin County, Kansas, seven miles southeast of Ottawa. A wooded limestone bluff with a southeasten exposure from thirty to eighty feet high forms the north bank of the creek for slightly less than half a mile, sloping gently toward the creek at its upstream end but rising abruptly with a very steep declivity at its other extremity (Plate II, figure 1). In addition to many deep crevices used by the snakes for hibernation quarters (Plate II, figure 2), loose slabs of rock scattered along the slope furnished satisfactory shelter during the summer months. Since the top of the bluff had been little frequented by human beings and the steeper end not pastured, many species of snakes and lizards were found in abundance during the spring and summer of 1926.

BREEDING HABITS

Mating

Only two published references to the time of mating of the Copperhead under normal field conditions have been discovered. Hay (1892, p. 386) in referring to this species

says: "As to the time of the pairing of the sexes, I have knowledge of only one observation. My friend, Rev. A. M. Hall, brought me from Western Pennsylvania two specimens of this species, which he took while pairing, on the 28th of August. Unfortunately, the female was disposed of before my investigation of this subject was begun."

Beyer (1898, pp. 19-20) records his observations as follows: "On April 12, 1895, a negro came to me with two magnificent copperheads, which he said he had caught the previous evening in a canebrake in the act of copulation. .... I did not notice anything until late in the evening of September 16, when the female ... brought forth seven young. .... I have certainly no reason to doubt the negro's statement, especially as a later dissection proved the other snake to have been a male."

In the course of these studies the act of mating has not been witnessed in the Copperhead. Field observations during the years of 1926, 1927 and 1928 suggested that the time to expect mating to occur normally was during April and early May. During this five or six-week period in the spring, Copperheads just emerging from their hibernating crevices were found in abundance at the Gould's Ford bluff described above. Often several were discovered together beneath the same rock. The sexes of such individuals were

checked but at that time no dissections were made to see if mating had taken place.

To determine whether or not the males were capable of producing or possessing spermatozoa in the genital tracts at all times during their active season, the vasa deferentia of freshly killed specimens were examined at intervals during the years of 1928 and 1929. The end of an excised vas deferens was gently pulled between a dissecting needle and a glass slide and the seminal fluid so obtained diluted with a drop or two of normal saline solution. Microscopical examinations of such preparations made at intervals during the months of April, May, June, July, August and October showed the presence of more or less active spermatozoa.

Two females were taken in company with males in the fall of 1928. In each case the pair was discovered beneath the same stone. One collected October 7 was dissected the following day and smears from the mucous membrane of the vaginae and uteri were examined microscopically. No spermatozoa were observed. The ovaries were in much the same condition as those of spring collected females. The follicles were small, the largest about 4.5 x 3 mm. in size. Another female collected October 30 had a large mass of viscous fluid in the posterior end of the right uterus and vagina. Preparations made from this and from the contents of the uteri at inter-

vals throughout their length, were allowed to dry in air and stained in Delafield's haematoxylin. Many deeply stained bodies thought to be sloughed epithelial cells were made visible but no spermatozoa were found. A similar examination revealed no spermatozoa in a smaller female which, however, appeared to be immature.

During the months of April and May, 1929, forty-three female Copperheads were examined. Of this number six were obviously immature, as shown by their small size and the relatively incomplete development of their gonads and genital tracts, and two others were probably immature. The remaining thirty-five which appeared to be adults were tested for spermatozoa by a microscopical examination of the contents of the vaginae. A vaginal sample was secured from the live snakes by the following method: A few drops of normal saline solution were injected by means of a sterile pipette into each vagina, the cloacal opening of which could be seen when the anal aperature was dilated. The washings of the vaginal mucosa, then mixed with the saline solution, were drawn back into the pipette and placed upon a slide. Both vaginae of each snake were examined in this way and after taking each sample the pipettes were rinsed carefully and allowed to stand for several minutes in strongly acid 70 percent. alcohol which was later removed by washing in dis-

tilled water. The tests were considered "positive" if active spermatozoa were present and "negative" if none were found.

Of the thirty-five sexually mature females examined, either by the above method or by taking smears from the genital tracts of snakes killed and dissected for other purposes, twelve were found to contain active spermatozoa in one or both vaginae or uteri. These females were examined within a few days of their capture and in most cases they were separated from males soon after they were received at the laboratory. It is not probable that any matings occured after the snakes were collected as they were observed frequently and, as is generally well known, the pit vipers rarely mate in captivity.

As an indication of the possible length of life of the spermatozoa in the vaginae of the females, observations on three individuals are of interest. Two of these were collected April 12, found "sperm positive" four days later, and dissected on April 23 and May 8 respectively. Active spermatozoa were still present in the first on April 23 but in the second examined May 8 only dead ones were present. A third female was collected April 7, contained active spermatozoa April 18, but when dissected April 30 all the sperm cells found were dead. If no copulation took place after

the snakes were captured, it would seem from these observations that the male germ cells may live within the body of the female eleven days and perhaps considerably longer.

Although observations on the breeding habits of snakes in general are few in number, the majority of those on record for the nearctic species report copulation in April and May. Of the snakes of the family Colubridae the following records of breeding individuals are of interest: Ruthven (1915) referring to one of the garter snakes, Thamnophis butleri (Cope), states that snakes of this species have been observed to breed at various times between April 9 and April 24, and that the time of breeding is probably determined by the prevailing temperatures during April; Perry(1920) observed the mating of Natrix sipedon (Linn.), a water snake, in May; Medsger (1927) saw two males of the hog-nosed snake, Heterodon contortrix (Linn.), mating with a dead female April 11; Truitt (1927) noted sexual excitement and mating behavior in the garter snake, Thamnophis sirtalis (Linn.), in June; and the writer has observed sexual union or pre-mating behavior in the pilot black snake, Elaphe obsoleta obsoleta (Say), and the diamond-backed water snake, Natrix rhombifera (Hallowell), in May and in Graham's water snake, Natrix grahamii (Baird & Girard), in April (Gloyd, 1928). Coues and Yarrow (1878, p. 278), however, state that individ-

uals of the plains garter snake, Thamnophis radix (Baird & Girard), in Dakota and Montana were taken in coitu in September and part of October.

For the poisonous snakes of the family Crotalidae a few observations are on record. Beyer (1898, p. 17), in addition to the note on the copperhead already referred to, reports finding a pair of cotton-mouth moccasins, Agkistrodon piscivorus (Lacepede), in coitu near New Orleans March 10; Mitchell (1903, p. 35) says that he has seen the Texas rattlesnake, Crotalus atrox (Baird & Girard), mating as early as March 15 and as late as June 20; Klauber (1927, p. 16) referring to the rattlesnakes of Southern California says: "Our local rattlesnakes mate in the spring and the young are born alive in the autumn." A pair of Massasaugas or pigmy rattlesnakes, Sistrurus catenatus catenatus (Rafinesque), were observed by Guthrie (1927, p. 13) in Iowa to attempt coition in the laboratory May 7. Of the same species Atkinson and Netting (1927, p. 42) write that they judge that in western Pennsylvania mating takes place in late April or early May.

Instances of late season mating are reported by Coues and Yarrow (1878, p. 268) referring to the prairie rattlesnake, Crotalus confluentus (Say), in Dakota and Montana who state that the pairing season of these serpents is in mid-

summer, when they have several times been observed in coitu, and by Hay in the paper already referred to (1892, p. 386) which recorded the mating of the Copperhead in Pennsylvania August 28. On Bois Blanc Island, Straits of Mackinac, Michigan, August 7, 1927, the writer secured a female and two male Massasaugas, Sistrurus catenatus catenatus, which had been killed by a summer resident of the island only a short time before. They were said to have been rolled together in a ball-like mass and one of the hemipenes of one of the males was everted when the specimen was picked up. A recent paper by Wiley (1929) describes two matings of the Texas rattlesnake, Crotalus atrox, in captivity. These occurred December 29 and August 5, but in these cases the snakes had been in captivity for a considerable period and had become quite tame and accustomed to the unnatural surroundings so that these dates can not be considered significant in a consideration of what normally occurs in the field. In the same paper Mrs. Wiley (p. 11) states that in nature but one litter of rattlesnakes occurs in a year. Mating takes place in the spring and the young are born in late August or in September.

The observations of the writer during the progress of these studies tend to confirm the idea that the mating of poisonous snakes in the spring is of most frequent occur-

rence and is presumably normal. By analogy with other vertebrates such as fishes, amphibians and birds, it may be assumed that the procreative instinct is stronger at this time. The fact that of the thirty-five adult females examined in the spring, twelve or 34 percent. had mated a short time previous to their capture, as indicated by the presence of vigorously active spermatozoa in their genital tracts, can safely be regarded as positive evidence if not complete proof of spring mating, for it seems very improbable that the spermatozoa so observed could have retained their strength and activity throughout the winter. Insufficient fall material has been examined, however, to prove that copulation does not occur at times other than during the spring months. The fact that males possessed active spermatozoa throughout the season when out of hibernation probably has little significance in this connection.

Gravid Females and the Birth of Young

Gravid females were collected in the Gould's Ford region on the following dates: July 14, August 19, 22, and 30. They were all found beneath large flat stones or in some sheltering crevice with the exception of two or three which were on rocky ledges (Plate II, figure 2), and one which was on top of the bluff in the green grass of a pasture. One

particular rocky crevice, in which gravid females were collected during three successive seasons, was for some reason especially attractive to the snakes. It was located in an open space on the top of the high end of the bluff (Plate II, figure 1) under the southeastern edge of a large immovable fragment of limestone (Plate II, figure 3). The cavity was a pocket-like recess extending back about ten or twelve inches with the opening about two inches high.

On three occasions more than one gravid female was discovered in the same location. Two in 1927 and three in 1928 were in the crevice described above, and in 1927 two others were sheltered by a flat stone four feet across. No males were found accompanying females during July and August.

The eggs developing in the uteri of the females were usually quite evedent when the snakes were handled, those under observation during the early summer becoming large enough to be noticeable about the middle of June. When the snakes were held by the neck, tail downward, a definite increase in the size of the posterior third of the body was easily seen and even with the snake on the ground in the normal position the enlargement of the abdomen was evident (Plate I). The eggs could also be felt and even counted by drawing the snake's body through the hand with thumb against the ventral side.

During the four seasons in which these studies were carried on fifteen captive females gave birth to young in the late summer and early fall, the dates ranging from August 23 to September 17 (see Table II, page 21). Parturition took place at night in every case except one. Although on several occasions the young were observed within a few hours after birth, sometimes while the moist prenatal membranes were still enclosing them, the process of parturition was observed with only two females.

The first of these had already brought forth two young snakes, one of which was crawling actively about the box and the other lying quietly within the membranes, when discovered at 1:00 p.m. A third young was extruded at 1:17 and a fourth at 2:00. Each of the three young snakes observed remained quiet about forty-five minutes after birth when they twisted their heads slightly, extended their necks rupturing the enclosing membranes, and began to explore their new surroundings. The prenatal yolk in one case had not entirely been taken into the body (Plate III, figure 1). As the young snakes became active the belly stalk pulled apart so that they were at once free of the fetal membranes.

The second female was observed about 9:30 p.m. moving restlessly about the box with nervous sideways twitching of the posterior part of her body. The tail was elevated to an

angle of about 45 degrees and lowered at intervals. Within a few minutes a fetus appeared in the cloacal aperature. The posterior third of the body of the female slowly moved from side to side and a peristalic wave moved the fetus a few millimeters at a time (Plate III, figure 3), and when about half extruded, one continuous wave-like motion pushed it smoothly through the remaining distance (Plate III, figure 4). The female had not changed the position of the anterior half of her body during the whole process, her only movements besides those necessary for the expulsion of the fetus being to flex the neck slightly, and she remained perfectly motionless for twenty minutes afterward. The extrusion of the young snake, from the time of its first appearance until completely outside, was accomplished in slightly less than ten minutes.

When abdominal movements began again the female shifted her position. The next mass moved toward the cloaca with difficulty and the snake appeared uncomfortable if not in actual pain. As it approached the cloaca it moved more slowly and the movements of the female were more labored. The tail was elevated at intervals but dropped after a moment or two of ineffectual straining. This behavior continued for nearly two hours when just a little before midnight the tail was suddenly elevated and a whitish-buff

colored mass appeared at the cloacal opening. It paused for about a minute and a half and then was forced out quite suddenly by a violent contraction of the abdominal muscles. The object proved to be a sterile yolk (Plate IV, figure 1), hard, solid and of irregular shape. The female rested again, resuming the abdominal peristalsis within twenty-five minutes. The next fetal mass moved more rapidly and easily toward the cloaca and forty-five minutes after the beginning of the movements a coil of the second young snake appeared beneath the elevated tail (Plate IV, figure 2), moving forward a few millimeters at intervals of two or three seconds (Plate IV, figures 2, 3 and 4) until it was completely extruded, the process taking in this case also about ten minutes.

The young snakes at birth were folded twice or three times within the membranes, their heads toward the middle of the mass (Plate III, figure 1), the part first presented in the cases observed being a bend of the neck. Unless the membranes were ruptured during parturition, as described above, the young of both the females made no effort to break through for about forty-five minutes. However, those of another brood observed soon after birth remained in the membranes for several hours, but as the day on which they were born was unusually cool and damp, it is probable that the

low temperature prolonged their post-natal quiescence for an abnormal length of time. Lynn (1929, p. 97) reports an abnormal case in which a young Copperhead remained alive within the dried prenatal membranes for nine days.

In emerging from the egg covering, the young snakes simply extended their necks, pushed their heads through and crawled out. The short body stalk remained attached to the ventral body wall ten to fifteen scales anterior to the anus but soon became dry and was lost completely during the first ten hours after birth.

Although the egg tooth was present, as noted by Dunn (1915, p. 37), it seemed to be unnecessary in rupturing the thin membranes. Ruthven (1908, p. 14) in describing the parturition of garter snakes does not mention the presence of egg teeth. Beyer (1898, p. 20) found them in Natrix grahamii but made no comment concerning them in describing the puncturing of the membranes in the cotton-mouth moccasin, Agkistrodon piscivorus. It is probable that this structure, so vital in the groups of snakes which produce tough shelled eggs, in the ovoviviparous species is in the process of phylogenetic degeneracy.

Period of Gestation

Definite records on the gestation periods in snakes are

very few in number. Only two for the genus Agkistrodon, given by Beyer (1898), have come to the attention of the writer. This author gives one case each for A. piscivorus, the cotton-mouth moccasin, and for A. mokasen, the Copperhead. A female of the former species mated March 10 and brought forth young August 17, with a gestation period of 127 days. A Copperhead believed to have mated April 11 gave birth to young September 16, with a gestation period of 128 days.

A summary of the published records on the birth of young in various parts of the United States (Table I), and data on fifteen broods studied by the writer (Table II), indicate that the end of the period of gestation ranges from August 23 to September 29, with September 10 representing the average date. Since observations in the Kansas region show that mating probably takes place in April and early May, the gestation period must be somewhere between 120 and 160 days in length. Considering Beyer's evidence, it seems probable that about 130 days is more nearly the approximate period, and that young born later in the fall are from matings later in the spring.

TABLE I. SUMMARY OF THE PUBLISHED RECORDS OF THE BIRTH OF YOUNG COPPERHEADS

Author and Year*	Locality	Birth of Young	Number in Brood
Beyer (1898, p. 20)	New Orleans, La.	Sept. 16	7
Ditmars (1907, p. 425)	New Jersey	Aug. 25	6
"	" "	Sept. 6	5
"	" "	" 7	4
"	" "	" 9	6
"	North Carolina	" 10	7
"	New Jersey	" 10	9
"	Pennsylvania	" 11	9
Dunn (1915, p. 37)	Haverford, Pa.	" 1	7
Brimley (1923, p. 115)	Raleigh, N. C.	- - - -	6
Reese (1926, p. 357)	West Virginia	Sept. 13, 15	3
Babcock (1926, p. 5)	Blue Hills, Mass.	" 29	6
Stadelman (1928, p. 67)	Glenolden, Pa.	Aug. 29	8
Lynn (1929, p. 97)	Baltimore, Md.	Sept. 24	7

*Complete references to each of these papers will be found in the section on literature cited.

TABLE II. BROODS OF YOUNG FROM CAPTIVE FEMALES

No. of Female	Length of Female; cm.	Date of Birth of Young	No. of Young in Brood
1	61.4	Aug. 23, 1925	5
2	59.5	Aug. 23, "	2
3	69.5	Aug. 25, "	6
4	57.0	Sept. 3, "	4
5	62.0	Sept. 6, "	3
6	65.5	Sept. 9, 1926	6
7	59.7	Sept. 13, "	4
8	66.5	Aug. 31, 1927	5 (Abortion)
9	69.0	Sept. 9, "	6
10	61.0	Sept. 17, "	3
11	63.5	Sept. 10, "	4
12	60.5	Sept. 10, 1928	4
13	64.0	Sept. 10, "	5
14	58.5	Sept. 10, "	2
15	67.0	Sept. 10, "	6

The ovarian eggs of the mated females dissected showed continuous enlargement during April and May. The uteri of one examined April 19 showed segmental enlargements about 15 mm. long, unusually well supplied with blood vessels and separated by slightly constricted portions about 5 mm. long. This may be a preparation on the part of the uteri for receiving the eggs after ovulation. As all gravid females examined after June 1 had eggs in the uteri, it may be assumed that ovulation takes place sometime during May.

Summary

1. Observations made in the field and microscopical examinations of the genital tracts of both sexes at different times of the year, indicate that mating in the Copperhead normally takes place soon after the snakes emerge from hibernation in the spring. It may be possible that a recurrence of the sexual instinct is present in the late summer or fall.

2. Gravid females collected at various times from July 14 to August 30 showed a certain gregariousness, two or three being drawn together by an especially desirable shelter, and pregnancy was indicated by the enlargement of the posterior third of the body.

3. Parturition occurred at night with all except one

of the fifteen females which brought forth young.

4. The young of the two females observed were expelled at intervals of approximately one hour, the time for the extrusion of a single fetus being about ten minutes.

5. Unless the prenatal membranes were ruptured in passage through the cloaca of the female, the young snakes remained quiet within them for nearly forty-five minutes.

6. When emerging the young snakes simply pushed their heads through the membranes, making no use of the egg tooth as far as could be observed.

7. Young were born in the late summer and early fall, between the dates of August 23 and September 17, making a gestation period of about 130 days, if mating can be assumed to occur about the middle of April.

8. Evidence from dissections of females indicated that ovulation occurred in May.

PRENATAL NUTRITION

Since in ovoviviparous snakes it must be assumed that an interchange of carbon dioxide and oxygen must take place between the uterine blood supply and the allantoic vessels of the embryo, the writer attempted to see if any evidence of the passage of nutriment to the embryo could be found.

Gross dissection showed that the uterine blood vessels

of pregnant females were greatly enlarged and much branched. A network of blood vessels surrounded the expanded portions of the uterus where each egg was located. The constricted parts of the uteri between each egg, which held the eggs in position, were relatively devoid of blood vessels. When the uterine wall was cut, the eggs could be easily removed without rupturing the membranes and the latter, as far as could be ascertained, were perfectly smooth. The uterine wall, however, when flattened out showed a uniform arrangement of small thickened areas, rosette-like in shape and barely perceptible to the naked eye. They were evenly distributed over the entire mucosa. In tissues stained in Delafield's haematoxylin and alcoholic eosin small capillaries could be traced into these areas. The course of the smaller capillaries, however, could not be traced in preparations stained in alum carmine. When portions of the egg membranes and uterine walls were sectioned transversely, the small thickened areas were seen to be in contact with the outer membrane of the egg. They appeared to be of equal abundance in the vicinity of the embryo and at the edge of the blastoderm on the ventral side.

These peculiar structures in the uterine mucosa, in such intimate relationship with the blood system, suggest the possible existence of an adaptation analagous to a pla-

centa. There is no proof, however, that these structures have any function other than that of facilitating gaseous interchange. Careful studies on this problem are much to be desired.

THE YOUNG

Observations on Newly-born Broods

The number of young in the fourteen broods for which definite published records are available (Table I) ranges from four to nine. A few more references, less definite than those given in Table I, may be mentioned. Allen (1868, p. 179) states that in Massachusets six females killed in September contained from seven to nine young each. Stejneger (1895, p. 405) gives the average number of young as between seven and nine. Mitchell (1903, p. 27) reports finding from three to eleven embryos in the uteri of gravid females in Texas. Surface (1906, p. 189) says that from six to ten young are born at a time and quotes Atkinson (Ann. Carnegie Mus., vol. 1) regarding a brood of six young born August 28 in Pennsylvania. Ditmars (1910, p. 338) states that about a dozen young are produced at birth. Hurter (1911, p. 208) gives the number of young as four to nine and records thirteen embryos in one snake on July 27 (Missouri).

Brimley (1923, p. 115) in North Carolina examined a female that contained eight eggs with small embryos June 13 and another with four larger embryos August 13.

Another paper by Kunze (1883, p. 1235) quotes newspaper clippings describing the finding of sixty and eighty-eight young copperheads in the bodies of females. These erroneous reports are either based on the confusion of the Copperhead with other species such as garter snakes or water snakes or are examples of the most extreme type of nature faking.

In the fifteen broods from the Kansas region born in the laboratory of the writer (Table II) the range in number of young is from two to six. Table II also shows that in general the larger females have the larger number of young.

In the entire series of young studied the ratio of the males to females was approximately 2 to 1. The variation in size for each sex is shown in Table III.

TABLE III. SIZE OF NEWLY-BORN YOUNG

	Average Length in Millimeters	Extremes	Average Weight in Grams	Extremes
Females	230.7	218 - 242	10.0	8.3 - 10.6
Males	237.5	223 - 247	10.5	8.6 - 14.0

Stadelmann (1928, p. 67) gave the average length of eight young as 21 centimeters and the average weight as 6 grams.

At birth the young were quite dark in color and their skins were glossy. The yellow tail, mentioned by Ditmars (1907, p. 424), was dull and clouded. After the first shedding of the skin, however, the general color was lighter, the gloss disappeared leaving the skin with a soft velvety texture, and the yellow of the tail became strikingly brilliant.

A decidedly plump appearance was caused by the mass of semi-solid yolk which had been taken inside the body. Dissections of four individuals permitted the weighing of the yolk during the first few hours after birth. It ranged from 15.8 to 29.2 percent. of the total weight of the snake. It was noticeably less in quantity on the second day and at the age of ten days in two snakes examined it was reduced to a mass of less than a half gram. At the age of fifteen days no yolk was present.

Babcock (1926, p. 5) reported ecdysis in a young Copperhead six days old and Lynn (1929, p. 97) states that six of a litter of seven shed at the age of twelve days.

In the majority of cases observed during the progress of these studies all the young of a single brood underwent

ecdysis at about the same time. In three litters only did the period of moulting occupy two or three days. The youngest age at which the skin was shed was three days and the oldest ten days, the greater number of the young observed shedding on the seventh or eighth day.

The anal glands, which in adult Copperheads produce a secretion of a decidedly penetrating odor, were not active in the very young. After the age of eight days, however, when a gentle pressure was applied at the base of the tail, a few small droplets of clear liquid with traces of the characteristic odor were obtained. One individual of this age ejected a fine stream through a distance of about an inch. In adults the secretion was well developed and much in evidence when the snakes were irritated by the firm hold of the neck which, for the safety of the operator, is necessary when measuring live snakes or extracting venom. A fine jet of this liquid was sometimes shot out to a distance of two or three feet from the duct of each gland. It seems to be used under these circumstances as a repellent in self defense. However, it is possible that it may have significance in connection with sexual attraction. The morphology and physiology of the anal glands of snakes have not been carefully studied.

That the venom of the very young of poisonous snakes is

more or less dangerous was maintained by Beyer (1898, p. 21) who suffered intensely from the bite of a ground rattler, Sistrurus miliarius (Linn.), eight days old, although he felt only a sensation comparable to that of a bee sting after the bite of a day-old cotton-mouth moccasin, Agkistrodon piscivorus (Lacepede). Atkinson (Surface, 1906, p. 189) wrote of having been bitten on the finger by a Copperhead eight days old. He also suffered from a painful inflamation which continued four days.

During recent years the subject has been discussed by several writers. Reese (1926, p. 357) made some observations which he thought indicated that Copperheads a month old are incapable of poisoning other animals although their fangs and venom glands are well developed. Viosca (1926, p. 328) quoted Beyer and offered the suggestion that the venom in young poisonous snakes may not be secreted until after the first day. Stadelman (1928) reviewed the comments of some of the previous writers and from tests made on a mouse and on himself concluded that Copperheads only six hours old are in possession of a completely functional venom apparatus capable of inoculating a dangerous amount of venom, particularly if the victim be very young or in poor condition.

With the desire to test the strength of the venom, the writer caused a young Copperhead, within an hour after its

birth, to bite the left hind leg of a twelve-gram albino mouse. Both fangs were imbedded in the flesh but no pressure was applied, care being taken not to increase the amount of venom beyond that which the snake would independently inject. A small drop oozed from one of the punctures. Within one minute pronounced edema and discoloration appeared on the bitten leg and the sole of the foot darkened from the normal pink to a dark purple. The swelling and discoloration caused by the extravasation of blood continued up the leg and thigh and within eight minutes the leg was paralyzed. At fourteen minutes the edema and darkening included the entire leg and the adjacent part of the body. The mouse died in slightly less than one hour. Post mortem examination revealed great subcutaneous extravasation in the entire leg and sacral region. The heart and lungs were darkened and congested and the large blood vessels appeared to be clogged. This experiment was repeated with another snake and a second mouse, the same typical symptoms of crotalidic poisoning taking place and death resulting in an hour and thirteen minutes.

As an indication of the later functional development of the glands, small clear drops of venom, light amber in color, could be extracted by gentle massage from snakes five days old, and some killed and fed upon small mice within a month.

Later Development of the Young

For the purpose of obtaining an indication of the probable age of Copperheads of different sizes, the size and age at which sexual maturity is attained, and the approximate rate of growth of the species, a size frequency graph was made for each sex. With the assumption that size is an indication of age, the number of individuals of similar length (measured to the nearest centimeter) was plotted vertically and the total length in centimeters horizontally. Only the measurements of specimens collected during the months of April and May were used.

The eighty-seven females fell into seven groups (Plate V, figure 1) as shown by the gaps where representatives of a size were few in number or entirely missing. The first group consisting of the smallest individuals with an average length of 21 cm. corresponds in size to that of the newly-born young and doubtless is made up of the young of the preceding fall. It is designated in the graph as Group 0. The individuals of the succeeding groups, I to VI inclusive, have an average length of 34, 45, 57, 61, 66, and 71 cm. respectively.

The males, 135 in number, fell into ten groups (Plate V, figure 2), Group 0 corresponding to the size of the young of the preceding fall with an average length of 27 cm. Year

groups I to IX have average lengths of 37, 48, 55, 61, 68, 74, 79, 85, and 91 cm. respectively.

Since no females under the length of 57 cm. were found by the examinations described on page 8 to have mated, and since none under this size gave birth to young (Table II, page 21), it seems probable that females attain sexual maturity during the third year.

A histological examination of the testes of a series of males through year groups II to IV showed that specimens under 52 cm. in length (Group II) were without mature germ cells in the seminiferous tubules of the testes. From this it follows that males also attain sexual maturity during the third year.

A further examination of the size frequency curves of Plate V shows that the rate of growth of both sexes is from ten to twelve centimeters per year during the first two years. It then slows up to an average of five or six centimeters per year for succeeding years, the decrease in growth rate being accompanied by the development and activity of the reproductive organs.

In regard to the length of life of the Copperhead, Boulenger (1914, p. 182) states that snakes of this species lived for ten years in the London Zoological Gardens in Regent's Park. One large male collected by the writer in

the spring of 1925 measured 90 cm. when secured. This would place it in year group IX indicating a possible age of nine years. It lived in the laboratory without hibernating until the fall of 1928 which, if the approximations of the size-frequency graph are fairly accurate, indicates a potential longevity of more than twelve years in the species.

Summary

1. The number of young in a single brood of Copperheads ranged from 3 to 13 in the published records and from 2 to 6 in the broods studied. In general the larger females had the larger number of young.

2. In the total number of young studied the ratio of sexes was approximately 2 males to 1 female.

3. The young snakes at birth averaged 230 mm. in length and 10.0 gm. in weight for females and 237 mm. in length and 10.5 gm. in weight for males.

4. The post natal yolk within the body cavity gradually decreased from the first day after birth and was completely absorbed at the age of fifteen days.

5. The first ecdysis took place at ages varying from three to ten days, the majority of young shedding on the seventh or eighth day.

6. The anal glands became functional when the young

snakes were eight days old.

7. Within an hour after birth young snakes possessed enough venom to cause death in 12 gm. albino mice; venom could be squeezed from the glands at the age of five days; and some killed and fed upon small mice within a month.

8. Size frequency graphs based upon 87 females and 135 males, and checked by dissections and histological studies, indicated that sexual maturity in both sexes is attained during the third year. As indicated by these graphs, the rate of growth is approximately 10 to 12 cm. per year during the first two years but averages only about 5 to 6 cm. per year thereafter.

9. Calculations based upon the size of a large male when captured and the length of time he lived in the laboratory indicate a potential longevity of 12 years for the species.

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EXPLANATION OF PLATES

Plate I

A gravid female Copperhead photographed June 27, 1929. Note enlargement of posterior part of the body due to developing eggs.

PLATE I

Plate II

Fig. 1. Southeastern end of the bluff at "Gould's Ford", Ottawa, Kansas.

Fig. 2. Ledges on top of bluff in which Copperheads were often found. The snakes hibernate in the deeper crevices.

Fig. 3. Crevice described on page 14 in which several gravid females were collected.

PLATE II

Fig. 1

Fig. 2

Fig. 3

Plate III

Fig. 1. Female No. 12 (Table II, page 21) with newly born brood. Note yolk sac with membranes and glossy appearance of the young which have begun to move about.

Figs. 2 - 4. The birth of the first young of female No. 14. See description on pages 15 and 16.

PLATE III

Fig. 1

Fig. 2

Fig. 3

Fig. 4

Plate IV

Fig. 1. Female No. 14 with sterile yolk just after extrusion.

Figs. 2 - 4. Birth of second young of female No. 14. Photographs taken at intervals of about three minutes. Described on pages 16 and 17.

PLATE IV

Fig. 1

Fig. 2

Fig. 3

Fig. 4

Plate V

Fig. 1. Size frequency graph of females collected during the months of April and May.

Fig. 2. Size frequency graph of males collected during the months of April and May.

PLATE V

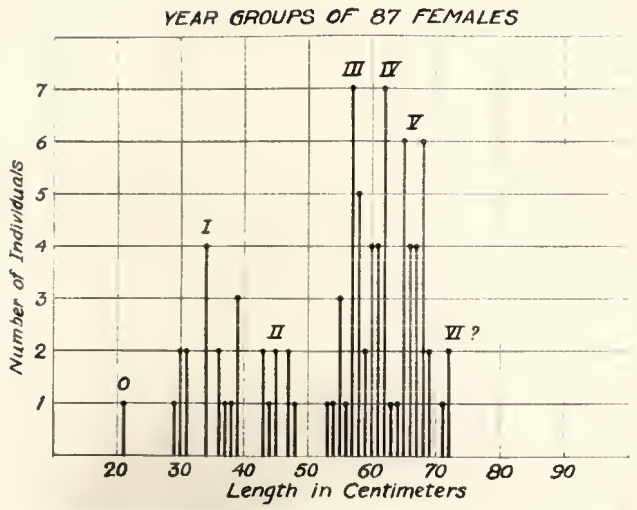

Fig. 1

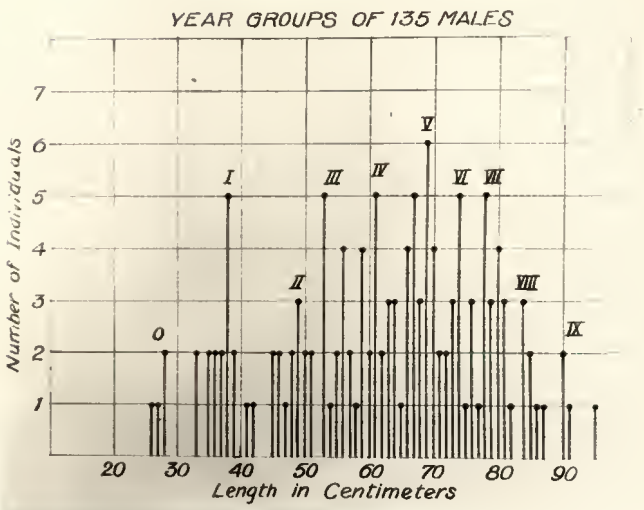

Fig. 2

Date Due
